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(71) Applicant: **WESTINGHOUSE ELECTRIC
CORPORATION**
Westinghouse Building Gateway Center
Pittsburgh Pennsylvania 15235(US)

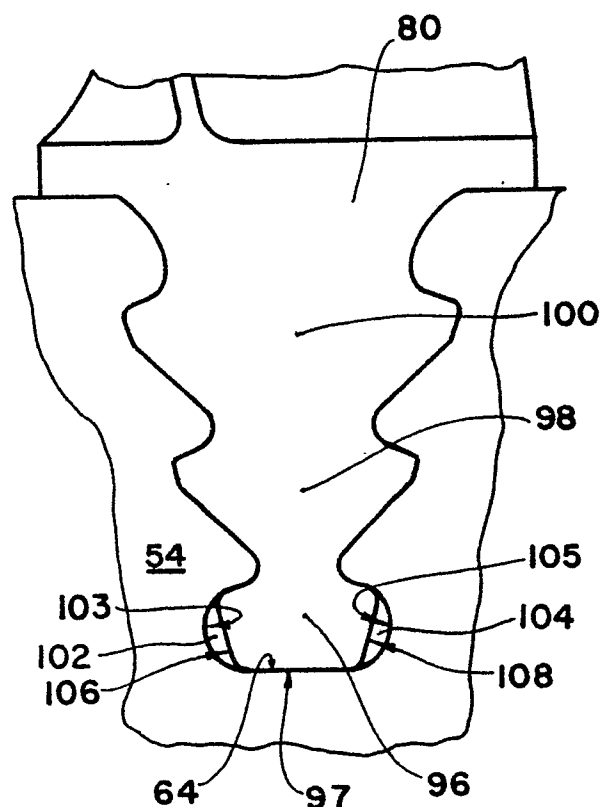
(72) Inventor: **Heinig, Roger Walter**
32 Yacht Haven
Cocoa Beach Florida 32931(US)

(74) Representative: **Fleuchaus, Leo, Dipl.-Ing. et al**
Melchiorstrasse 42
D-8000 München 71(DE)

(54) Side-entry grooves for mounting turbine blades.

(57) A rotor assembly for a steam turbine (10), wherein the rotor (12) has a plurality of rotor blade mounting portions (44, 46, 48, 50, 52, 54) with side-entry mounting grooves (56, 58, 60) having two symmetrically contoured opposite side walls (66, 68) and a bottom wall (64) and wherein each blade root portion (80) is substantially conforming in shape to each corresponding mounting groove, with cooling passages (102, 104) disposed on opposite sides of the bottom most lug portions (96) between the adjacent surface areas of the mounting groove (56-60) and the lug portions (96) adapted to permit passage of cooling steam therethrough.

FIG. 7



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SIDE-ENTRY GROOVES FOR MOUNTING TURBINE BLADES

This invention relates generally to steam turbines and, more particularly, to side-entry grooves arrangements for mounting turbine blades in the grooves.

A steam turbine can include a combination of low pressure, intermediate pressure, and/or high pressure steam turbine elements which are coupled together to provide a single power output. Each steam turbine includes a rotor having a plurality of rotating blades mounted thereon in rows. Usually, the blades of a given row are identical to each other. The rotating blades of a row extend radially outwardly from an outer surface of the rotor, with the rows being spaced apart. The rotating blades of one row differ in shape from those of the other rows; most noticeably, the rotating blades of each row, or stage, vary in length depending on position along the rotor.

Each rotating blade, regardless of row, has a foil portion extending radially outwardly from the rotor and a base portion for mounting the blade to the rotor. The base portion includes a root which is fitted into a mounting groove provided for each blade of a row, and a platform integrally formed at the proximal end of the foil portion. The foil portion has a tip at the distal end and may have a twist profile from the proximal end to the distal end, or may be parallel-sided. It is common to provide shrouds at the tips as separately added or integrally formed components.

A stationary cylinder is coaxially supported around the rotor and has a plurality of stationary blades mounted on an inner surface thereof. The stationary blades are arranged in rows which, when the cylinder is assembled with the rotor, alternate with rows of rotating blades. The stationary blades of one row are shaped differently from those of the other rows, although all stationary blades have a foil portion. The tips of the foil portions may be shrouded together by a series of shrouds. Some stationary blades have a base portion which includes a root and a platform. Others have the foil portion welded directly into blade rings, with no root or platform.

The root of each stationary blade may be provided with a side notch which, when the root is fitted into the groove, aligns with the annular recess. The side notch and the annular recess together define a space which is common to both the cylinder and the root. When the space is filled with caulking material, the cylinder and root become interconnected.

Rotor blade grooves provided in the rotor for mounting the rotor blades are usually geometrically more complex than the mounting grooves provided

for stationary blades. Moreover, the roots of the rotating blades and the rotor are subjected to substantially greater stresses than corresponding roots of stationary blades.

Some turbines have turbine rotor blades mounted in what are referred to as "side-entry" grooves provided in the rotor. When mounted, the rotor blades extend radially outwardly from the rotor in rows which are disposed circumferentially around the rotor. Instead of having a single annular groove for mounting the plurality of rotor blades which constitute a row, a side-entry groove arrangement includes, for a given row, a series of equidistantly spaced apart side-entry grooves, each side-entry groove of the series being provided for each rotor blade of the row. Although the side-entry grooves are usually equidistantly spaced, sometimes spacing is varied to facilitate assembly of a closing blade.

A typical side-entry groove starts at the outer surface of the rotor as an opening which tapers inwardly towards a bottom of the groove. A series of undulations are provided between the opening and the bottom of the groove symmetrically on opposite side walls of the groove. A typical root of a corresponding turbine rotor blade has a shape which substantially conforms to that of the groove. The undulations provide a series of interlocking steps. The undulating side walls also make it impossible to insert the root into the groove radially relative to the rotor.

In a side-entry groove, the root is pushed into the groove substantially parallel to the turbine rotor axis, and therefore, an interlocking can be achieved. Tolerances for both the root and groove are very precise. A root contour tolerance envelope for contact surfaces typically varies along the contour of the root from 0.0025 to 0.0127 mm. A groove contour tolerance envelope for contact surfaces typically varies along the profile of the groove from about 0.015 to 0.02 mm. Basically, a precise fitting between the root and the groove is required such that the maximum clearance between the root and groove is extremely small, on the order of about 0.4 mm.

There is a general reluctance to change rotor blade root and groove configurations once a particular design has been developed. This is because it may have taken months or even years of meticulous calculation to arrive at a particular design. Sometimes, slight variations in rotor blade root and groove profiles lead to unacceptable decreases in the function or performance of the blades or the rotor. Given that the tolerances between the root and the groove are critical, changes in the profile of

either or both goes against conventional wisdom.

Through experience, it has been proven desirable to provide cooling slots in the mounting grooves so as to allow steam to act as a cooling fluid below the outer surface of the rotor. Conventionally, the cooling slots have been formed by cutting the groove deeper. The deeper cut groove is cut during the original manufacture of the turbine rotor; it is an essential part of the design. The practice of cutting a deeper groove has been used specifically to the first one or two rows of the intermediate pressure section of a fossil-fueled turbine.

This approach has several drawbacks. In particular, the slot formed by cutting away the bottom of the groove tends to increase both rotor nominal stress and rotor stress concentration. Moreover, a special cutting tool is required for cutting the groove. Although these drawbacks have been partially outweighed by gains in heat transfer, a need exists for cooling slots which provide adequate heat transfer and minimize increased rotor nominal stress and rotor stress concentration.

It is therefore the principal object of the present invention to provide cooling slots in steam turbine rotor blade mounting grooves which minimize rotor nominal stress and which can be made without special tools.

With this object in view, the present invention resides in a rotor assembly for a steam turbine, wherein the rotor has a plurality of rotor blade mounting portions formed circumferentially thereon, a plurality of side-entry mounting grooves formed in each of the plurality of mounting portions equidistantly spaced on the circumference of the rotor, and being substantially axially oriented with respect to the rotor, each mounting groove having two symmetrically contoured opposite side walls and a bottom wall; with at least one row of rotor blades mounted to the rotor at one of the plurality of mounting portions in the plurality of mounting grooves, the rotor blades within each such row being substantially identical to each other, and each blade having a root portion, a platform portion, and a foil portion; each root portion being substantially conforming in shape to each corresponding mounting groove; characterized in that cooling passages are disposed on opposite sides of said bottom-most lug portions between the adjacent surface areas of the mounting groove and the lug portions adapted to permit passage of cooling steam therethrough.

The two cooling passages or slots may be formed by cutting into opposite side walls of the mounting groove, or they may be formed by cutting opposite sides of the bottom-most lug portion of the root portion diagonally from each side thereof to the bottom thereof.

There may also be a single cooling passage between the bottom of the mounting groove and the bottom of the bottom-most lug portion of the root portion of each rotor blade. This passage or slot is formed by cutting away a bottom portion of the bottom-most lug portion.

The invention will become more readily apparent from the following description of a preferred embodiment thereof shown, by way of example only, in the accompanying drawings, wherein.

FIG. 1 is a partial, longitudinal cross-sectional view of a known steam turbine, showing a portion of a rotor, a turbine casing, a cylinder, stationary blades and rotor blades;

FIG. 2 is a partial longitudinal cross-sectional view of the rotor illustrated in FIG. 1;

FIG. 3 is an enlarged, partial cross-sectional view taken along line III-III of FIG. 2, and showing a portion of the side-entry grooves used for mounting the rotor blades to the rotor of FIG. 1;

FIG. 4 is a top view of the side-entry grooves shown in FIG. 3;

FIG. 5 is a front view of a rotor blade mounted on the rotor of FIG. 1;

FIG. 6 is a partial side view of two rotor blades of two adjacent rows mounted on the rotor of FIG. 1;

FIG. 7 is an enlarged front view of a rotor blade root mounted in a rotor groove of a first preferred embodiment of the present invention;

FIG. 8 is a partial front view of a rotor blade root illustrating a second, preferred embodiment of the invention;

FIG. 9 is a partial front view of a rotor blade root representing a third, preferred embodiment of the present invention.

FIG. 1 partially illustrates a portion of a steam turbine 10 which includes a rotor 12 (partially shown), and a stationary cylinder 14 (partially shown) which completely surrounds the rotor 12. A plurality of rotor blades 16, 18, 20, 22, 24, and 26 are mounted in rows on the rotor 12. Each of the rotor blades is mounted in a different row. Each row is disposed circumferentially on the rotor 12. Each rotor blade extends radially outwardly from an outer surface of the rotor 12. Each of the six rotor blades illustrated in FIG. 1 is disposed in a separate row.

The cylinder 14 supports a plurality of stationary blades 28, 30, 32, 34, 36, and 38 which also are disposed in a plurality of corresponding rows. As shown in FIG. 1, the stationary blades alternate with the rotor blades. A housing 40 (partially shown) envelops both the cylinder 14 and the rotor 12 and is provided with steam seals 42 which allow the rotor 12 to rotate without letting steam escape between the rotor 12 and the housing 40. Steam seals 42 are also provided between the tips of the

rotor blades and the cylinder, and between the tips of the stationary blades and the rotor.

Referring now to FIG. 2, the rotor 12 is shown in greater detail with the blades 16-26 and all other structure removed. The rotor 12 is provided with a plurality of rotor blade mounting portions 44, 46, 48, 50, 52, and 54, each extending circumferentially on the rotor 12.

FIG. 3 illustrates an enlarged cross-sectional view of a portion of the mounting portion 54 shown in FIG. 2. The mounting portion 54 is provided with a plurality of side-entry mounting grooves 56, 58, and 60 which extend inwardly from an outer surface 62 of the mounting portion 54. Each mounting groove has a bottom wall 64 and opposite side walls 66 and 68. The opposite side walls 66 and 68 are symmetrically undulating and taper inwardly. A bottom space 70 is defined by the bottom wall 64 and a pair of opposite side lobes 72. Additional pairs of lobes 74 and 76 define increasingly larger spaces as viewed upwardly from the bottom space 70.

FIG. 4 shows the mounting grooves 56, 58, and 60 from a top view, and further illustrates grooves 78 which help facilitate securing the rotor blades within respective mounting grooves.

FIG. 5 illustrates a typical rotor blade 26 which includes a root 80, a platform 82, a foil portion 84 and a shrouded tip portion 86. The shroud is integrally formed with the blade, but may be separately formed. In the latter case, the shroud may be riveted onto the blade tip by deforming a projection from the blade tip, known as a tenon. When the rotor blade 26 is mounted on the mounting portion 54, as seen in FIG. 6, a bottom of the platform 82 is substantially flush with the top of the mounting portion 54. As is known in the mounted position, a groove 88 of the platform 82 is in alignment with the corresponding groove 78 of the mounting groove 56 (not shown). Each root 80 has a series of necks 90, 92 and 94 which increase in width from the lower-most neck 90 to the upper-most neck 94. These necks define lugs 96, 98, and 100, which also increase in width from the bottom-most lug 96 to the upper-most lug 100.

A first preferred embodiment of the present invention is illustrated in FIG. 7 wherein the root 80 is received within the mounting groove 56 of mounting portion 54. Cooling slots 102 and 104 are provided on opposite sides of the lug 96, and are formed by cutting into the side walls 66, 68, respectively, of the mounting groove 56 at the bottom space 70. The cooling slots 102 and 104 are defined by a space between cut-away surfaces 103 and 105 of the mounting groove 56 and sloping side walls 106 and 108 of the bottom-most lug 96. In contrast to the known practice of cutting a deeper groove to create a space between the bottom

wall 97 of the bottom-most lug 96 and the bottom wall 64 of the mounting groove 56, the opposite side cooling slots 102 and 104 avoid increasing the rotor nominal tangential stress and reduce the rotor tangential stress concentration.

A variation of the FIG. 7 embodiment is illustrated in FIG. 8, wherein the bottom-most lug 96 has its bottom corners cut-away to form oppositely angled surfaces 110 and 112, which are symmetrically disposed about a centerline 114 of the root 80. Broken lines 116 and 118 represent either the former outline of the root 80 before cutting, or the current profile of the bottom space of the mounting groove. Opposite side cooling slots 120 and 122 are defined by the spaces between the angled surfaces 110 and 112 and a portion of the mounting groove bottom wall and side walls.

In the embodiment of FIG. 8, stress patterns were modeled by computer to determine the effect of the opposite side cooling slots 120, 122. Stress was calculated based on centrifugal loading, with all lugs 96-100 in perfect contact with corresponding areas of the mounting groove 56. As a result of the computer modeling, it was determined that peak elastic stress at the bottom neck of the root (numeral 90 in FIG. 5) increased by only 8%. The lower amount of stress is accompanied by a greater area of heat transfer and a greater uniformity of flow around the circumference of the rotor, compared to the conventional approach of deepening the groove. Moreover, standard root cutters could be used instead of a special tool which would be required to cut deeper, special grooves.

Referring to the embodiments of FIG. 9, broken line 124 represents a portion of the bottom-most lug portion 96 that has been cut-away to form a cooling slot 126. The cooling slot 126 is defined by the space between bottom wall 128 of the truncated lug portion 96 and a bottom wall of the mounting groove, which may also be represented by the broken line 124. The portion of the mounting groove which helps define the cooling slot 126 includes portions of the opposite side walls of the mounting groove as indicated by the curved end portions of the broken line 124.

The embodiment of FIG. 9 was also tested by computer modeling for stress induced by centrifugal loading. A calculated 14% increase in the peak elastic stress at the bottom neck resulted. The advantage to the embodiment of FIG. 9 is that the groove can be cut with standard cutters.

In the embodiments of FIGS. 7-9, the cooling area is approximately 32 mm² in cross section. Although FIG. 8 has proven to have stress minimizing ability over the embodiments of FIGS. 7 and 9, all are deemed improvements over the known technique of enlarging the bottom of the mounting groove.

Claims

1. A rotor assembly for a steam turbine (10), wherein the rotor (12) has a plurality of rotor blade mounting portions (44, 46, 48, 50, 52, 54) formed circumferentially thereon, a plurality of side-entry mounting grooves (56, 58, 60) formed in each of the plurality of mounting portions equidistantly spaced on the circumference of the rotor, and being substantially axially oriented with respect to the rotor (12), each mounting groove having two symmetrically contoured opposite side walls (66, 68) and a bottom wall (64), with at least one row of rotor blades (16, 18, 20, 22, 24, 26) mounted to the rotor (12) at one of the plurality of mounting portions in the plurality of mounting grooves, the rotor blades within each such row being substantially identical to each other, and each blade having a root portion (80), a platform portion (82), and a foil portion (84), each root portion (80) being substantially conforming in shape to each corresponding mounting groove, characterized in that cooling passages (102, 104) are disposed on opposite sides of said bottom-most lug portions (96) between the adjacent surface areas of the mounting groove (56-60) and the lug portions (96) adapted to permit passage of cooling steam therethrough.

2. A rotor assembly as recited in claim 1, characterized in that each cooling passage (102, 104) is defined by a space between a cut-away surface (103, 105) of the side wall of the mounting groove and an adjacent surface (106, 108) of the bottom-most lug portion (96) of the root portion.

3. A rotor assembly as recited in claim 2, characterized in that each cut-away surface (103, 105) of the side wall of the mounting groove is arcuately shaped.

4. A rotor assembly as recited in claim 1, characterized in that the bottom-most lug portions (96, 98, 100) of each root portion (80) has opposite side walls which taper inwardly toward the bottom end of the root portion (80) so as to define said passage (102, 104).

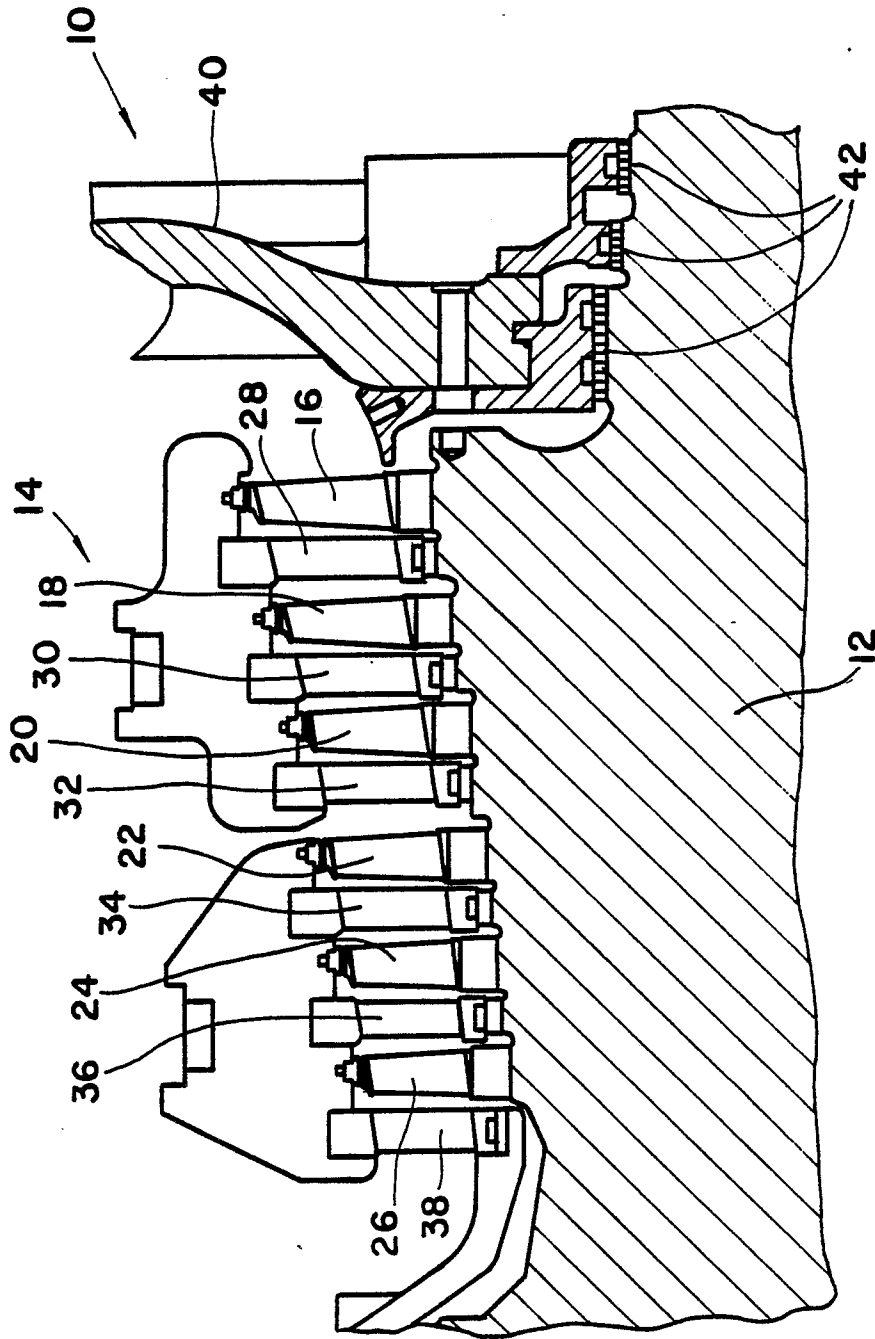
5. A rotor assembly as recited in claim 4, characterized in that each cut-away surface of the lug portion has a flat, inclined surface (110, 112) extending from one side wall of the lower-most lug portion (96) to the bottom wall of the lower-most lug portion (96).

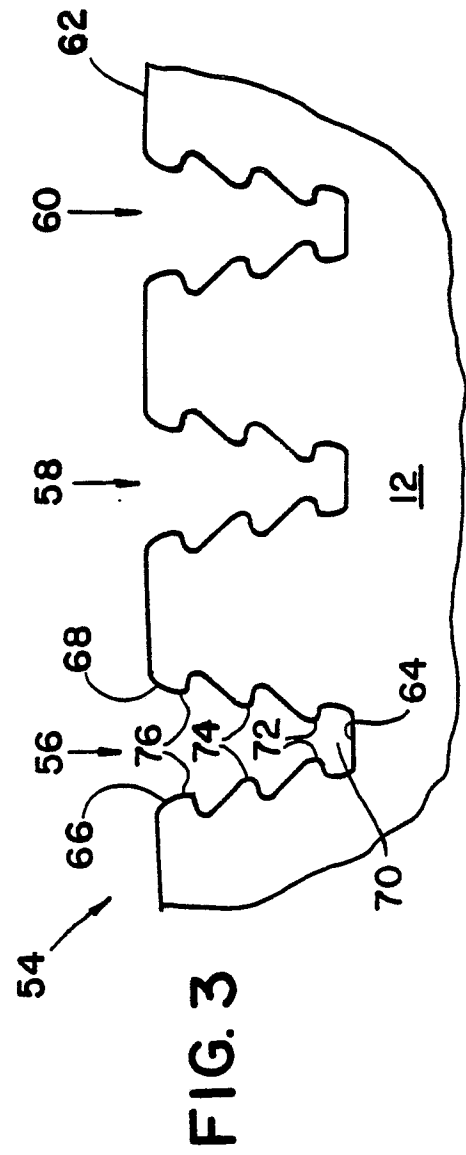
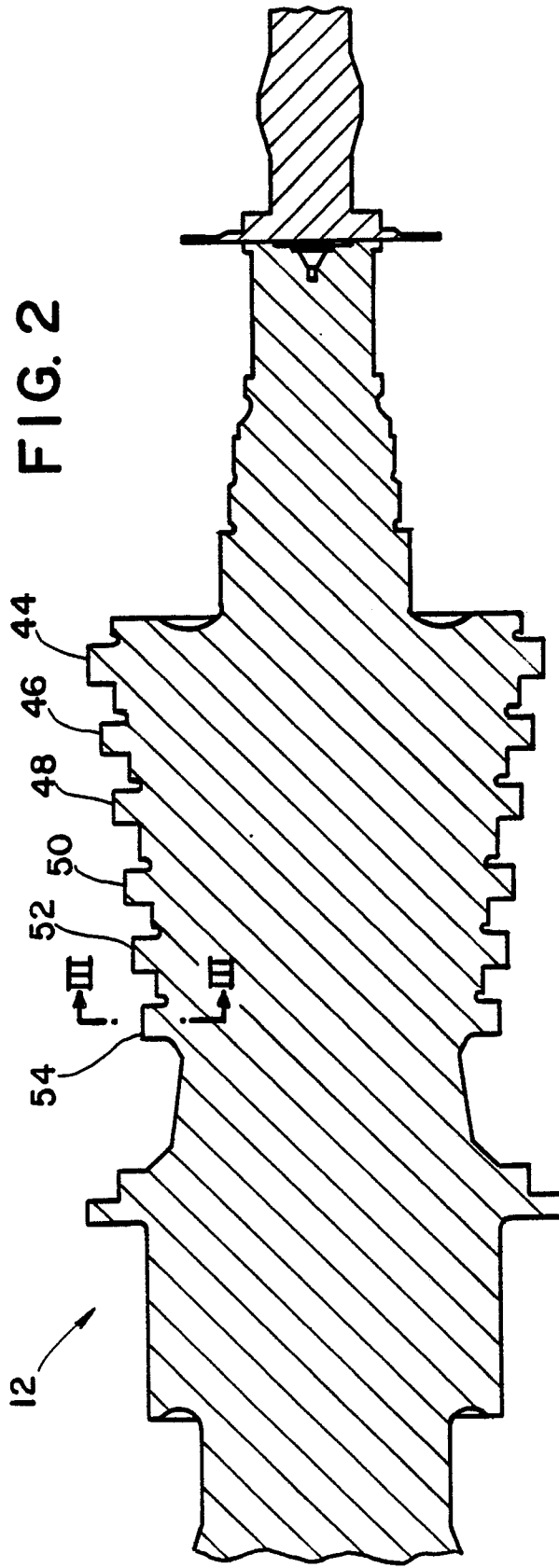
6. A rotor assembly as recited in claim 4, characterized in that the cooling passages are formed by a space between a cut-away surface (128) of the lower-most lug portion (96) and the bottom wall (124) of the mounting groove, the cut-away surface (128) defining a flat bottom wall of the lug portion parallel to and spaced from the bottom wall (124) of the mounting groove.

7. A rotor assembly as recited in any of claims

1 to 6, characterized in that the tolerances for contact surfaces between each assembled mounting groove and rotor blade root portion ranging between 0.0025 mm and 0.023 mm, and the area of the two cooling slots (102, 104; or 120, 122) is about 32 mm².

FIG. 1 (PRIOR ART)





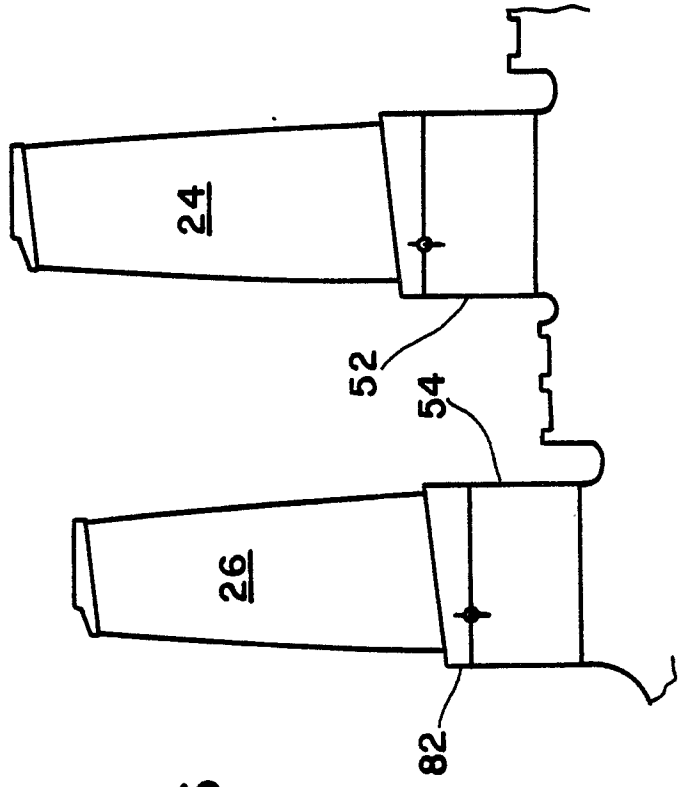
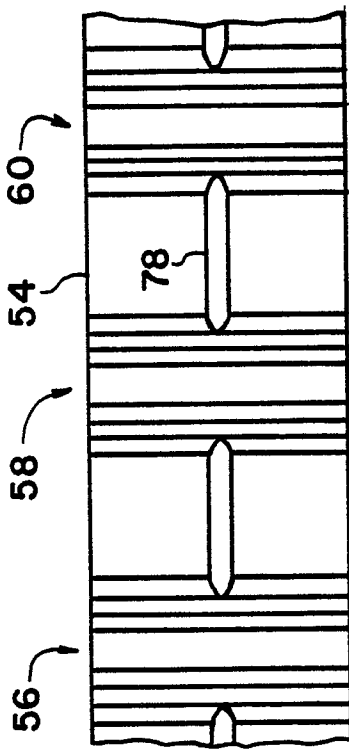
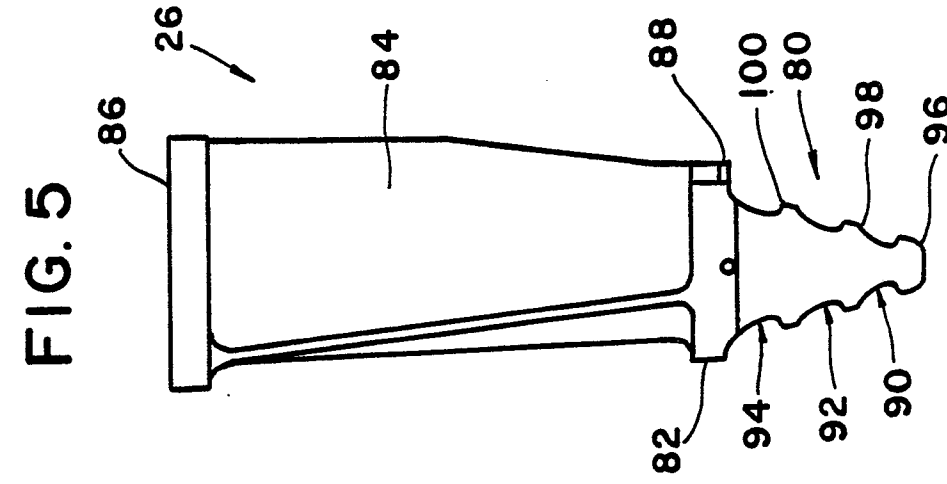


FIG. 7

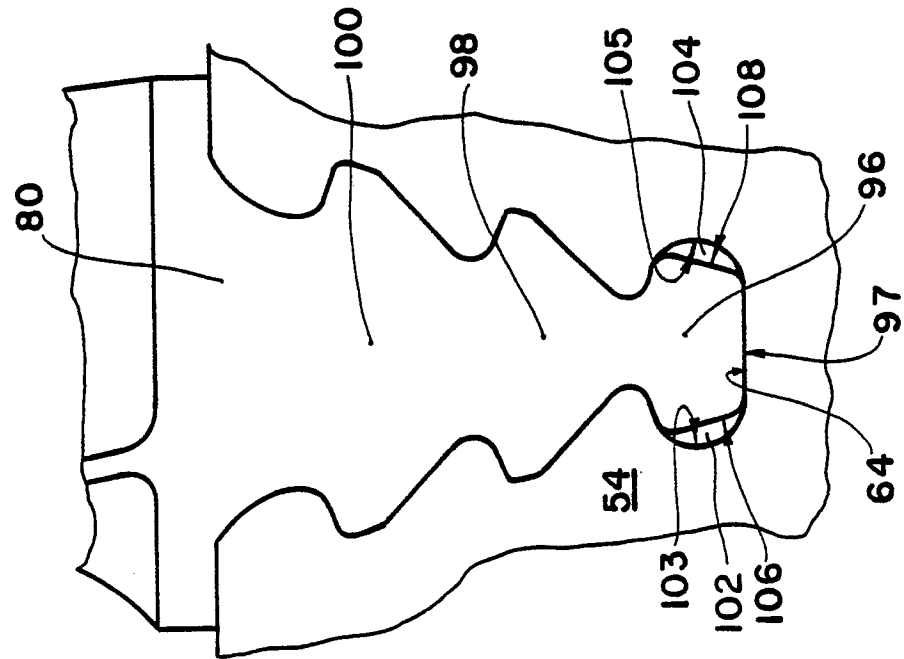


FIG. 8

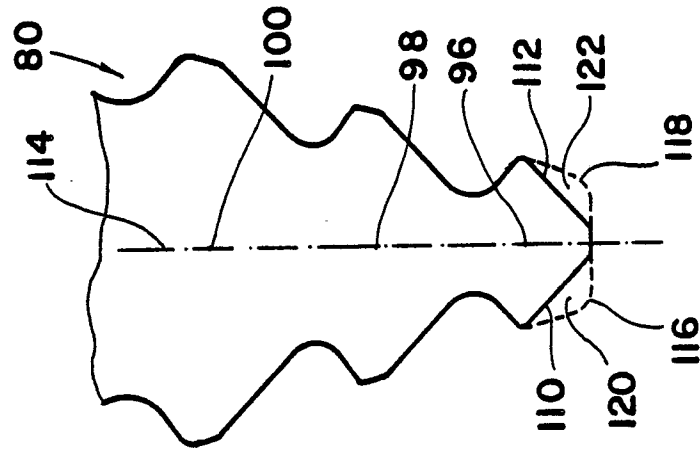
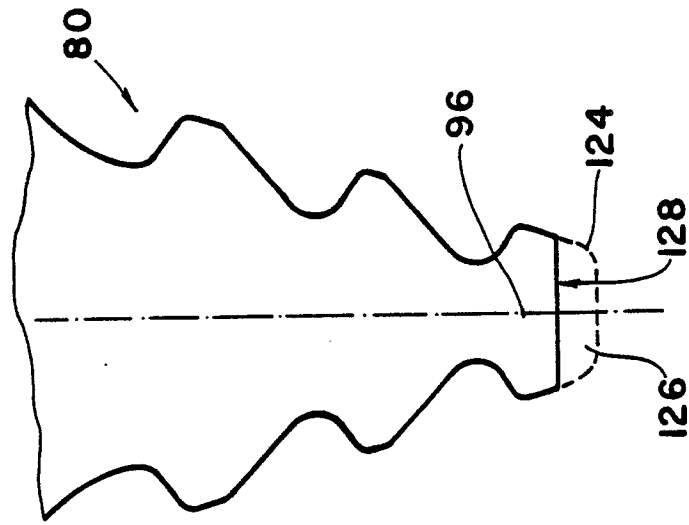


FIG. 9





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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	DE-A-1928184 (SCALZO) * page 2, line 23 - page 3, line 6 * * page 4, line 33 - page 5, line 6 * * page 9, line 28 - page 10, line 2; figure 4 * ---	1-6	F01D5/30 F01D5/08
A	DE-B-1076446 (MAGHON) * the whole document * ---	1	
A	GB-A-1183835 (MUDRAK) * the whole document * ---	1	
A	DE-A-1953711 (JERICHA) * figures 2-4 * ---	1	
A	US-A-2858103 (WAUGH) * the whole document * ---	1	
A	CH-A-495496 (SCHMIDT) * the whole document * ---	1	
A	GB-A-1211188 (GENERAL ELECTRIC) * page 2, line 50 - page 2, line 100; figure 3 * ---	1	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	FR-A-1526683 (BORIS) * figure 3 * ---	1	F01D
A	GB-A-579316 (CONSTANT) * the whole document * ---	1	
A	US-A-3045968 (WILLIS) * figure 3 * -----	1	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 25 OCTOBER 1989	Examiner IVERUS D.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			